Majorana Coupling by the Boundary of a Planar Topological Josephson Junction

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   Coupling to an environment can be a huddle for detecting Majorana zero modes. We theoretically study a planar Josephson junction made on the surface of a three-dimensional topological insulator, taking into account the influence of gapless boundary modes outside the Josephson junction. The coupling of the junction state to the boundary modes results in the hybridization of the Majorana zero modes in the junction mediated by the boundaries, modifying the signatures of the topological Josephson junction. By analyzing a proper model to describe the boundary effect both analytically and numerically, we discuss the effect of the boundary modes on the signatures of the Majorana modes such as 4π periodic current-phase relation and Fraunhofer patterns.